A scenario for a 5-year run plan and the implications

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- Official sPHENIX technical note in progress…

http://www.phenix.bnl.gov/WWW/publish/nagle/sPHENIX/nagle_sphenix_scenartionote_draft06132017.pdf

- Excel spreadsheet used also available here…

http://www.phenix.bnl.gov/WWW/publish/nagle/sPHENIX/nagle_sphenix_rates_update05162017.xlsx

The spread sheet includes the values used for the original sPHENIX proposal.

- This incorporated new C-AD numbers documented in 05/11/2017 note:

http://www.rhichome.bnl.gov/RHIC/Runs/RhicProjections.pdf

Table 1: Five-year run plan scenario (2022–2026) for sPHENIX. The recorded luminosity (Rec. Lum.) and first sampled luminosity (Samp. Lum.) values are for collisions with z-vertex $|z| < 10$ cm. The final column shows the sampled luminosity for all z-vertex values, relevant for calorimeter only measurements.

Year	Species	Energy [GeV]	Phys. Wks	Rec. Lum.	Samp. Lum.	Samp. Lum. All-Z
2022	Au+Au	200	16.0	7 nb^{-1}	8.7 nb^{-1}	34 nb^{-1}
2023	p+p	200	11.5	—	48 pb^{-1}	267 pb^{-1}
2023	p+Au	200	11.5	—	0.33 pb^{-1}	1.46 pb^{-1}
2024	Au+Au	200	23.5	14 nb^{-1}	26 nb^{-1}	88 nb^{-1}
2025	p+p	200	23.5	—	149 pb^{-1}	783 pb^{-1}
2026	Au+Au	200	23.5	14 nb^{-1}	48 nb^{-1}	92 nb^{-1}

Au+Au @ 200 GeV recording minimum bias at 15 kHz
More conservative C-AD ramp up and mean of MIN/MAX projections
Assume 60% sPHENIX uptime in 2022-23, 80% in later years

Just recording straightaway at 15 kHz for |z| < 10 cm …
47 billion (2022) + **96 billion** (2024) + **96 billion** (2026) = Total **239 billion events**

For topics with Level-1 selective trigger (e.g. high pt photons), one can sample within |z| < 10 cm a total of 550 billion events. One could consider sampling events over a wider z-vertex for calorimeter only measurements, 1.5 trillion events.

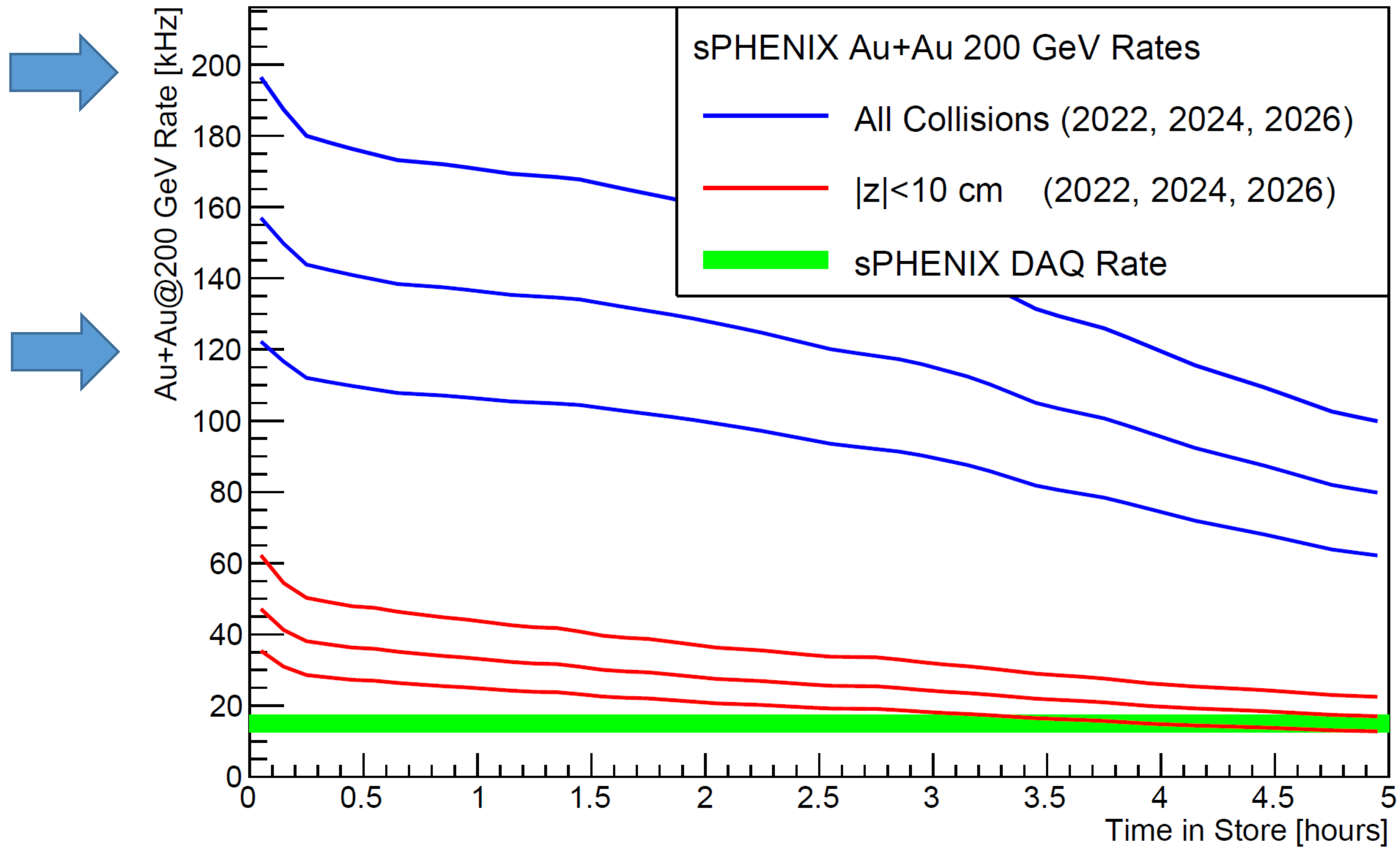

Figure 3: Estimated Au+Au at 200 GeV collision rate as a function of time in store for all collisions (blue) and collisions within ± 10 cm (red). The bottom to top set of curves in each color are for the mean luminosity and f_{z10} for the 2022, 2024, 2026 projected Au+Au at 200 GeV running periods. Also shown as a green band is the sPHENIX DAQ Rate of 15

Created with the sPHENIX ROOT style (thanks Peter)…

https://wiki.bnl.gov/sPHENIX/index.php/Plot_template

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p+p @ 200 GeV mostly sampling physics with Level-1 triggers
More conservative C-AD ramp up and mean of MIN/MAX projections
48 pb^-1 (2024) + **149 pb^-1** (2026) = Total **197 pb^-1**

Note in the original sPHENIX proposal, more optimistic numbers had 104 pb^-1 in 10 weeks. Thus, physics projections with this multi-year run plan will have a factor of x2 more statistics.

Documentation of Level-1 trigger efficiencies in p+p and p+Au now in CDR draft.
We need to be very careful about heavy flavor hadrons /jets and what can and cannot be triggered on.

Number of cryo-weeks …

In the sPHENIX proposal with guidance for only two-years of running, we were told by the ALD to assume 30-cryo weeks per run (i.e. be aggressive).

Weeks	Designation
0.5	Cool Down from 50 K to 4 K
2.0	Set-up mode 1 (Au+Au at 200 GeV)
0.5	Ramp-up mode 1 (8 h/night for experiments)
10.5	sPHENIX Initial Commission Time
16.0	Data taking mode 1 (Physics)
0.5	Controlled refrigeration turn-off
30.0	Total cryo-weeks

Table 6: Example cryo-week run plan for the first sPHENIX run in 2022 with Au+Au at 200 GeV collisions.

First run of 30 cryo-weeks, assume additional 10.5 weeks of commission time.

Other runs fit with 28-30 cryo-weeks each.

Specific guidance from ALD/DOE on numbers of weeks?

Charge Particle Flux and TPC/Tracking…

My understanding for the TPC and charge distortions is that what matters is the highest interaction rate (over all z-vertices) scaled by the $dN_{ch}/d\eta$.

Table 8: Charged particle instantaneous rate (max). These values are the maximum projected values during the five-year run plan and are from collisions over all z-vertex values.

System	Energy	$dN_{ch}/d\eta$	Highest Rate	$dN_{ch}/d\eta$/second
p+p	200 GeV	2.29	12.9 MHz	28×10^6
p+Au	200 GeV	9.16	2.8 MHz	29×10^6
Au+Au	200 GeV	190	219 kHz	45×10^6

Need technical note documenting that these are the specifications for the TPC (and MAPS etc.) to be able to handle…

- Can the TPC handle 219 kHz Au+Au rate of charged particles?
- If not, then what? If not, then this run plan does not quite make sense.
- Recent TPC conference talks still quote 100 kHz (?)
- These rates also need to feed into DAQ data volumes for the TPC.

Radiation and SiPMs…

Overall radiation is an issue for various components – e.g. SiPMs.
There is a contribution from beam-loss, beam-scrape (hard to calculate).
There is also a contribution from collisions – which should roughly scale at the total integrated collision rate x $dN_{ch}/d\eta$ x running time.

System	Energy	$dN_{ch}/d\eta$	Run	Integrated Charged Particles
p+p	200 GeV	2.29	Run-15	2.5E13
p+p	200 GeV	2.29	2023	3.7E13
p+p	200 GeV	2.29	2025	11.0E13
p+Au	200 GeV	9.16	2023	3.2E13
Au+Au	200 GeV	190	Run-16	2.7E13
Au+Au	200 GeV	190	2022	5.3E13
Au+Au	200 GeV	190	2024	16.0E13
Au+Au	200 GeV	190	2026	17.0E13

How to scale integrated charged particles to dose at the detector?
Need documentation on lifetime sPHENIX dose for SiPM lifetime or replacement plan….

Trigger Requirements…

In particular for p+p and p+Au, we need to sample the luminosity with selective Level-1 triggers.

First pass update on Level-1 trigger simulations for single photons, jets, single hadrons, and Upsilons.

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Rejections of order 5,000 - 10,000 are needed to get down to 1-2 kHz of bandwidth allocation for different physics topics.

Dennis and Erin Bossard (CU Undergraduate) have been running sPHENIX GEANT simulations to calculate p+p @ 200 GeV trigger efficiencies and rejections.

So far, using tower 2x2 sums but without emulation of detailed trigger electronics.

1. Direct photons
2. Reconstructed Jets
3. Hadrons (i.e. narrower Calorimeter energy cluster)
4. Upsilons

Next steps include extensions to p+Au and then Au+Au (for a few very high pT areas)…

New areas include lower pT heavy flavor hadrons…

Full emulation of trigger electronics (e.g. 8 bit limit on 2x2 sums)

1. Direct photons

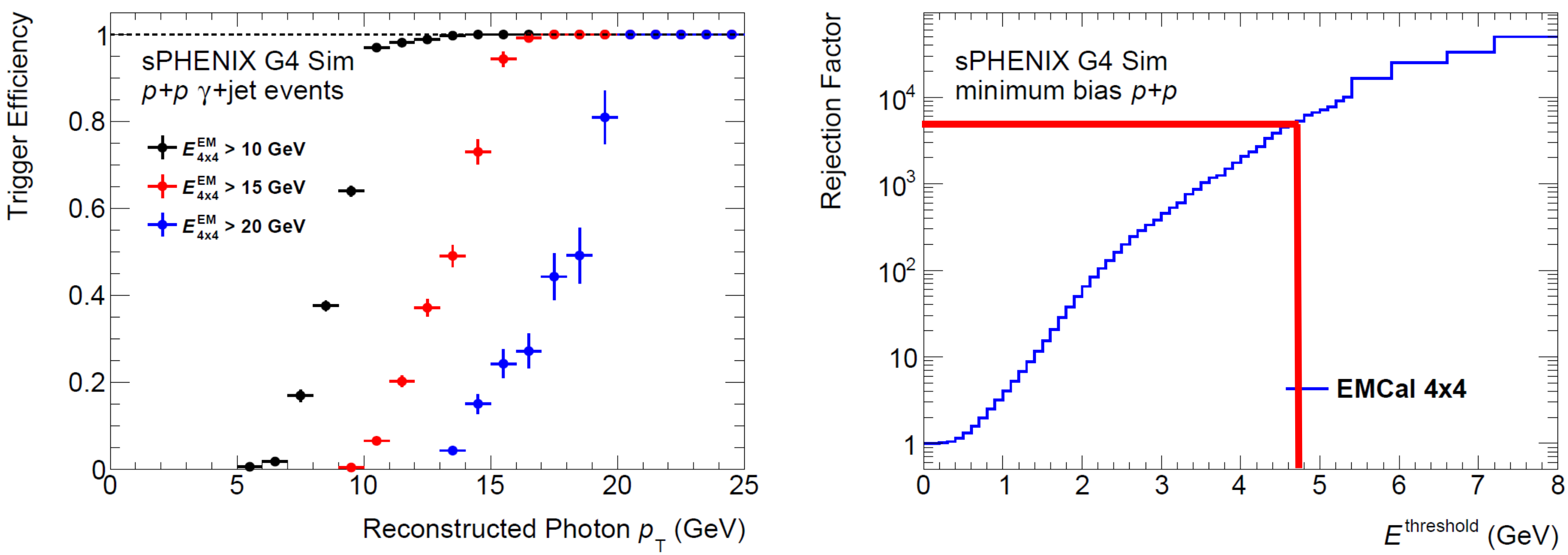


Figure 8.6: *Left:* Trigger efficiency for photons with respect to the reconstructed photon p_T. For this plot, PYTHIA 8 events with the prompt photon switch turned on and $\hat{p}_T > 8$ GeV were used. The efficiency is shown for three different window energy threshold using the EMCal 4x4 trigger. *Right:* Rejection factors in minimum bias $p+p$ collisions for EMCal 4x4 window energy thresholds.

2. Reconstructed Jets

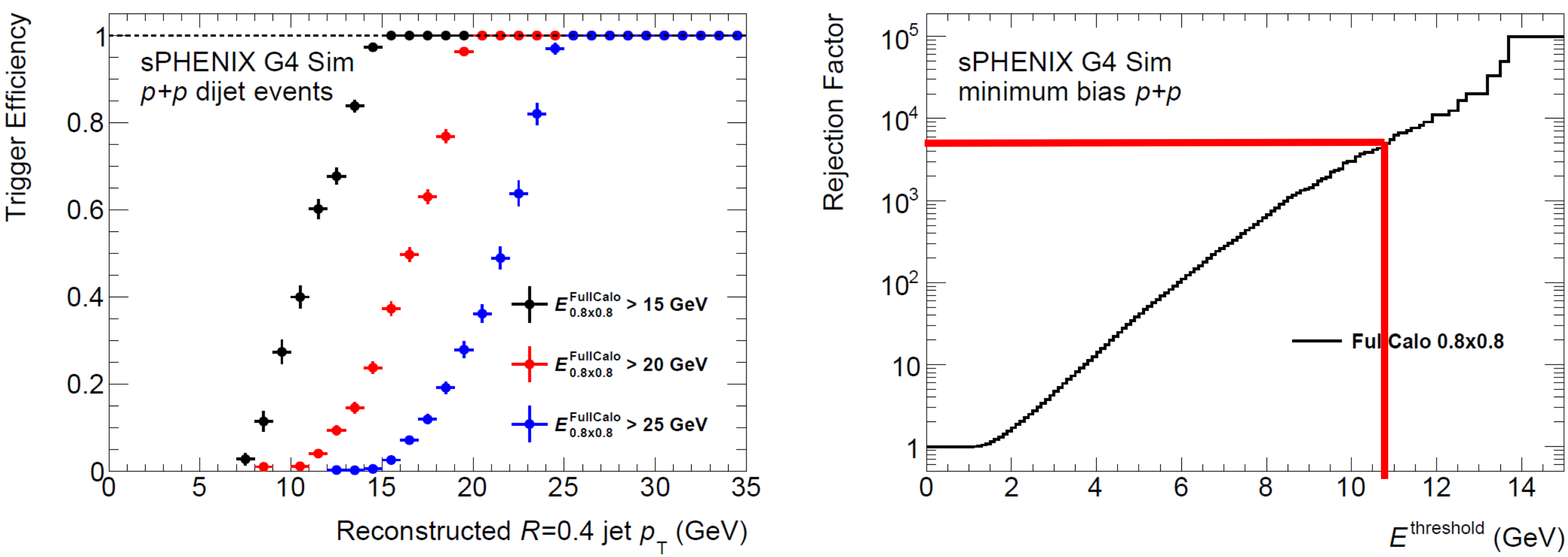


Figure 8.7: *Left:* Trigger efficiency for jets with respect to the (offline) reconstructed anti-k_t $R = 0.4$ jet p_T, based on requiring a minimum energy in a $\Delta\eta \times \Delta\phi = 0.8 \times 0.8$ region of the calorimeters. For this plot, PYTHIA 8 events with the hard QCD switch turned on and $\hat{p}_T > 20$ GeV were used. The efficiency is shown for three different window energy thresholds. *Right:* Rejection factors in minimum bias p+p collisions for FullCalo 0.8×0.8 window energy thresholds.

3. Hadrons…

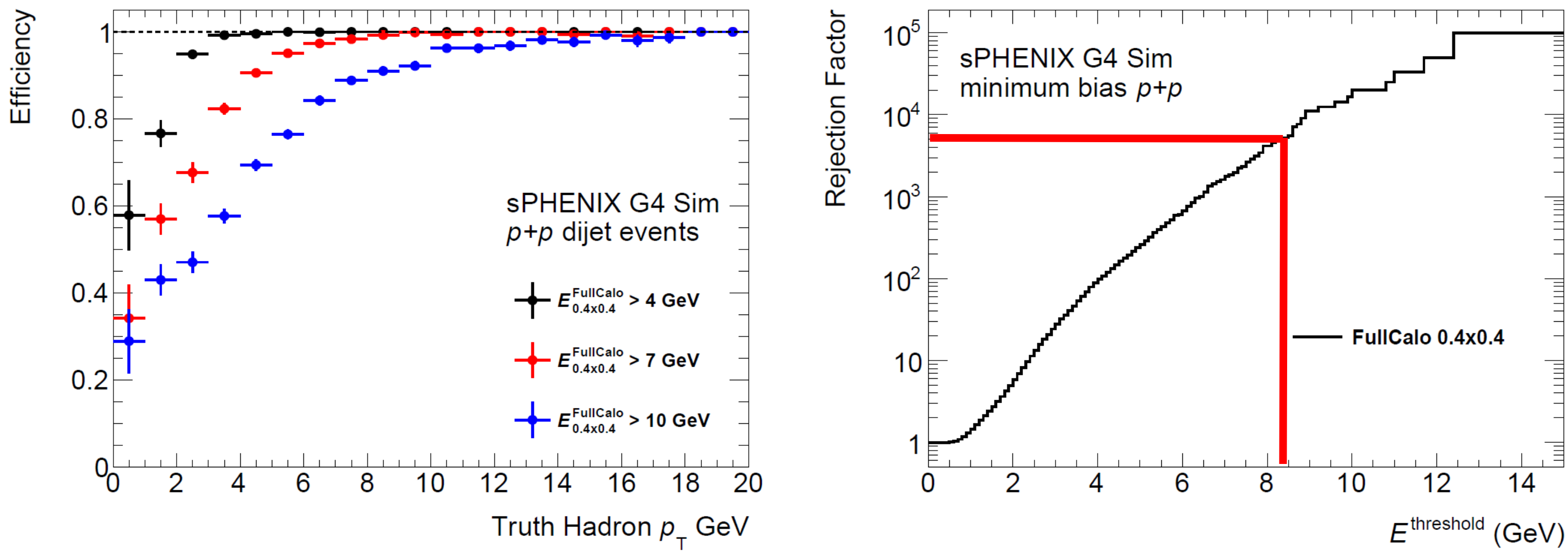
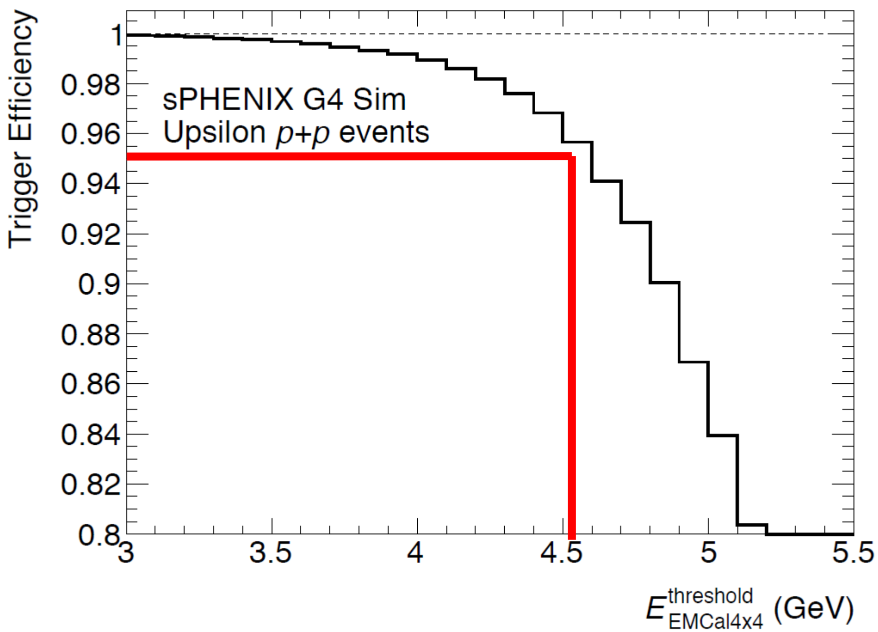


Figure 8.8: *Left:* Trigger efficiency for high-p_T hadrons with respect to the truth-level hadron p_T. The efficiency is shown for three different window energy threshold using the the FullCalo $\Delta\eta \times \Delta\phi = 0.4 \times 0.4$ hadron trigger. For this plot, the efficiency is determined in the same PYTHIA 8 hard-QCD $\hat{p}_T > 20$ GeV samples used to determine the jet trigger efficiency. In this case, for the purposes of firing the trigger, a hadron benefits from the fact that it is likely to be in close proximity to other hadrons in the jet which contribute to the energy in the FullCalo sliding windows. Thus, this estimate of the efficiency is most appropriate for the case of hadrons inside moderate-p_T quark or gluon jets (e.g. a separate study is needed to estimate the trigger efficiency for hadrons in charm or beauty jets). *Right:* Rejection factor in minimum bias p+p collisions for FullCalo 0.4×0.4 window energy thresholds.

4. Upsilons…



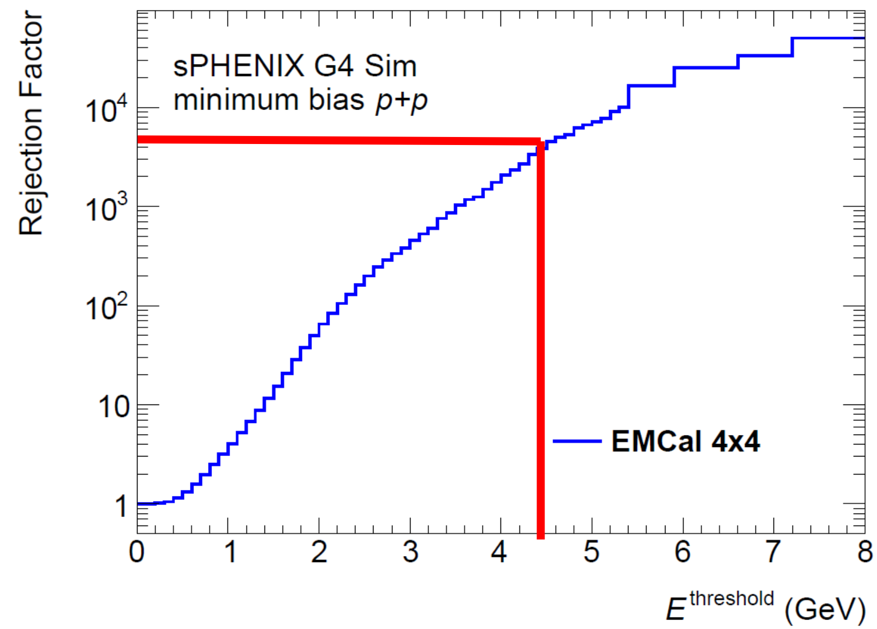


Figure 8.9: *Left:* Trigger efficiency for Upsilons decaying to two electrons, both of which are in the sPHENIX acceptance. The event sample used is PYTHIA 8 events with generator-level filtering on the decay electron and positron kinematics. The efficiency is shown as a function of the required EMCal 4x4 window threshold. *Right:* Rejection factor in minimum bias $p+p$ collisions for EMCal 4x4 window energy thresholds (same as the right plot in Fig. 8.6).

All look in reasonable shape for p+p case for "core sPHENIX physics deliverables"…. Probably the bigger question is <u>what more can we deliver</u>…

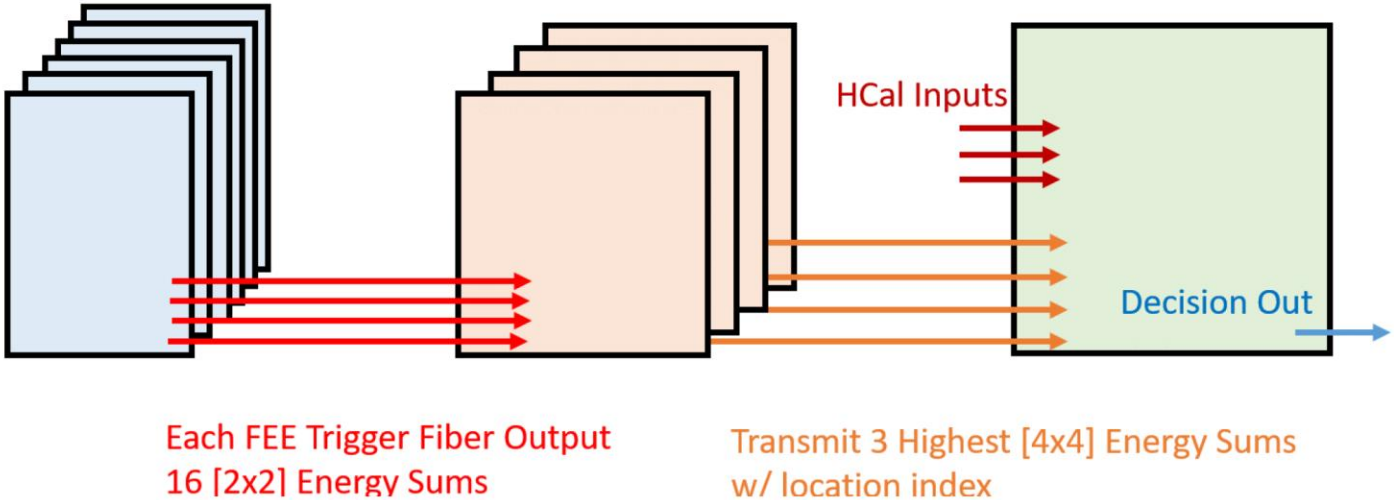


Figure 8.10: Schematic for the calorimeter Level-1 trigger systems. The FEE sends primitives with 2×2 non-overlapping tower energies to the Level-1A modules. The Level-1A modules may contain data from approximately 25% of the entire detector. The Level-1A modules then send non-overlapping energy sums in $\Delta\eta \times \Delta\phi = 0.2 \times 0.2$ regions to the Level-1B board for full jet trigger algorithm processing, where the entire detector coverage is needed. The Level-1A modules also send out a truncated list of the highest energy EMCal 4×4 overlapping towers.